

AD-A225 076

DTIC FILE COPY

(4)

Technical Report 1343
April 1990

Oceanographic and Weather Data for Ice Camp Crystal During the AREA 88 Experiment

R. R. Judd

DTIC
EX ECTE
AUG 9 1990

D

CO 2

Approved for public release; distribution is unlimited.

00 00 00 00 00 00

NAVAL OCEAN SYSTEMS CENTER

San Diego, California 92152-5000

J. D. FONTANA, CAPT, USN
Commander

R. M. HILLYER
Technical Director

ADMINISTRATIVE INFORMATION

The work described in this report was performed from March 1988 to April 1988. It was performed under project number RJ14I77/N03A and program element 62314N for the Office of Naval Technology, Arlington, Virginia. The study was performed by a member of the Acoustics Branch (Code 541) of the Naval Ocean Systems Center (NOSC), San Diego, California. This effort represents part of an ongoing study by the Acoustics Branch to understand arctic acoustics.

Released by
J. H. Richter, Head
Ocean and Atmospherics
Sciences Branch

Under authority of
J. D. Hightower, Head
Marine Sciences and
Technology Department

SUMMARY

OBJECTIVES

During March and April of 1988, the U.S. Navy conducted an AREA (Arctic Research and Environmental Activities) experiment in the central Arctic to take and record environmental measurements of that arctic region. These measurements were CTD (Conductivity, Temperature, and Depth) stations, ocean current, wind speed, air temperature, ice temperature, barometric pressure, and camp positions.

RESULTS

CTD data were collected to about 700 meters, providing information to calculate sound-speed profiles. In addition, a time series, showing internal-wave activity, was collected at 181 meters. In the CTD profiles, fine structure (steps) is seen. This structure occurs at about 2 meters above the temperature maximum (at around 280 meters) and at about 40 meters below the maximum.

Wind speed ranged between calm and 15 meters per second. Ocean current and drift varied between less than 1 centimeter per second to 30 centimeters per second. To show their interrelationship, wind speed, ocean current, and drift are analyzed.

RECOMMENDATIONS

Recommendations are as follows:

- Log navigational data by placing an ARGOS transmitter at the site for the duration of the project.
- Analyze the regularity of the fine structure to determine if it causes peculiar acoustic effects.
- Install a multiyear system to log ice temperatures during an entire arctic year.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input checked="" type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



CONTENTS

INTRODUCTION	1
OBJECTIVE	1
DESCRIPTION OF TRIP	1
ICE CONDITIONS	1
CAMP POSITION	2
Satellite Navigator	2
System ARGOS	2
ENVIRONMENTAL DATA COLLECTION	2
Data Logger	2
Ocean Current Meter	3
Temperature Measurements	3
Temperature Sensors	3
Air Temperature	3
Ice and Water Temperature	3
Wind Speed and Direction	3
Barometric Pressure	4
CTD Stations	4
DATA	5
NAVIGATION	5
Camp Position	5
Camp Drift Rate and Direction	7
WIND SPEED AND DIRECTION	7
TEMPERATURE	7
BAROMETER	9
OCEAN CURRENT	9
CTD OPERATIONS	12
PROFILES	12
TEMPERATURE TIME SERIES	14
COMPARISONS OF DRIFT, CURRENT, AND WIND	14
CONCLUSIONS	16
NAVIGATION	16
CTD DATA	16
TEMPERATURE	16
WIND, CURRENT, AND FLOE DRIFT	16
REFERENCES	19
APPENDIX A	A-1

FIGURES

1. Map of Camp Crystal position	5
2. Drift direction	6
3. Wind speed and direction	8
4. Temperature measurements	9
5. Barometric pressure	10
6. Current meter results	11
7. A typical temperature profile showing step-like structure	13
8. An example of salinity spiking	13
9. Station 10 temperature (function of time); station 9 temperature (function of depth)	14
10. Drift rate/current speed	15
11. Drift direction/wind direction	15

TABLE

1. CTD stations: date, time, and position data	12
--	----

INTRODUCTION

OBJECTIVE

Environmental data were collected to provide information needed for analyzing acoustic data collected at the Crystal site. These data also aid in evaluating the AREA 88 acoustic system and provide information necessary for designing future arctic systems.

A secondary purpose was to collect basic oceanographic parameters. Data collection in the Arctic is expensive, and the current database is not extensive. Such information is useful in understanding the physics driving the arctic environment, and can be used as input for propagation models and other models simulating arctic behavior.

DESCRIPTION OF TRIP

All people and equipment involved with AREA 88 were initially staged from Thule Air Base, Thule, Greenland. In mid-March, a base camp, Camp Ruby, was set up on shore-fast ice, about 20 miles from station Nord in northeast Greenland. A runway, capable of handling ski-equipped C-130 aircraft, was built by logistic contractors at Ruby, at which all science in this part of the Arctic was conducted or staged. The Danish station at Nord was also used for fueling aircraft and temporarily housing AREA-88 personnel.

Camp Crystal was set up via air drop on 31 March, with the first scientists arriving on 7 April, and the last scientist arriving on 12 April. Camp Crystal was set up as two small camps, separated by about 1 mile, to permit acoustic decoupling between camps. The data in this report were recorded at the acoustic camp known as Crystal Two. However, the ARGOS transmitter, which supplied the camp position for drift calculations, was located at Crystal One, as were the runway and the logistic personnel. Crystal Two personnel consisted of scientists from the Naval Ocean Systems Center (NOSC) in San Diego and from the Naval Research Laboratory (NRL) in Washington, DC.

The original intent was to operate Crystal until about 4 May. However, on 29 April, the decision was made to abandon the camp, because of an ice breakup at Crystal One and probable loss of the runway, and also because of deteriorating weather conditions. The runway did, in fact, break up as the last flight left on 1 May.

ICE CONDITIONS

The runway at Crystal One was located on a smooth, 1-meter thick, refrozen lead. This allowed the project aircraft to land on wheels and carry a heavier payload than would be possible with only skis.

Crystal One was established at the edge of this lead on a second-year flow about 2.5-meters thick. About 1 mile away, Crystal Two was established on a first-year flow, approximately 1.75-meters thick.

On about 19 April, a lead formed approximately 500 meters south of Crystal Two. It then closed and formed into a pressure ridge which remained active for the remainder of the project. On about 23 April, a lead formed between the camps. Fortunately, this lead closed up and did not form a large pressure ridge, thus, allowing people and material to be transported, unhampered, between Crystal Two and the runway. Because of warm temperatures during much of the trip, leads did not refreeze and remained active.

CAMP POSITION

The position of a camp situated on sea ice depends upon the vagaries of wind, ocean currents, and the transpolar drift. Although the initial position may be chosen, within the limits of finding a suitable site, this position will change over time. Hence, camp position must be determined and recorded at frequent intervals. Two methods were used at Camp Crystal to verify its position: a satellite navigator system and system ARGOS.

Satellite Navigator

A Magnovox MX 4102 Satellite Navigator was used locally to determine the camp position, which was logged by hand at convenient times. The satellite navigator also provided the information for the positions of CTD (Conductivity, Temperature, and Depth) stations. The positions provided by this instrument had more scatter than those provided by ARGOS, and the quality of a particular fix was affected by the position of a particular satellite.

System ARGOS

The second method used an ARGOS satellite transmitter. System ARGOS is a satellite system that allows oceanographic buoys to transmit data back to a centralized collection system. ARGOS also determines the position of the transmitter. An ARGOS transmitter was working at the Crystal site for almost the entire experiment, providing the most frequent account of camp position. These data were not available locally at Crystal, but were recorded along with other buoy data at system ARGOS, and made available on computer tape when requested. ARGOS data are used to calculate camp drift rate and directions, and to map camp positions.

ENVIRONMENTAL DATA COLLECTION

Data Logger

Every 10 minutes, the data logger system automatically recorded the following environmental parameters:

- Ocean Current
- Wind Speed and Direction
- Air Temperature
- Ice Temperature
- Water Temperature
- Barometric Pressure

An HP-71 hand-held computer was used as a system controller. Using an internal timer, it turned on the data logger system every 10 minutes, recorded the various parameters and stored them for later analysis, and then turned itself and other equipment off.

The current data were obtained from the current meter data terminal using an RS-232 interface. Other sensor parameters were measured using a Hewlett Packard Data Acquisition and Control Unit (DACU), Model 3421A.

The DACU is the heart of the data logger system. Basically a multimeter with multiplexing capability, the DACU facilitates measuring ohms or volts. This unit also allows any of 30 inputs to be

chosen under program control using the HP 71. Two of the inputs were configured as switches, with one used as the power on/off switch for the current meter and its data terminal.

Ocean Current Meter

A Niel Brown direct-reading acoustic current meter was used to measure ocean current. The data terminal on the surface supplies power to the current meter and outputs the current meter parameters via an RS-232 interface. For use in a remote arctic camp, the data terminal was modified to run on 12 Vdc, and the LED readouts of current meter parameters (normally available) were disabled to save power. The current meter has an internal compass, and a two-axis measuring capability is available to record current direction, as well as speed. Currents are measured in the horizontal plane and not in the vertical. Depth-sensor and temperature-sensor outputs on the current meter were also recorded.

Temperature Measurements

Temperature Sensors. Thermistors made by YSI (series 4000) were used for sensing temperature. A calibration tank was used to obtain calibration points for temperatures at 3, 4, 5, 6, 7, and 8 degrees centigrade. Combined with points at -50 and +20 degrees centigrade from the standard calibration curve supplied with the sensors, a cubic equation was fit to the natural log of the thermistor resistance values. These equations were used to reduce field data.

Air Temperature. The thermistor used for air temperature was mounted in a short section of white PVC tube with holes drilled in the side to allow free air flow. This sensor was mounted about 1.5 meters above the ice.

Ice and Water Temperature. To gain a better understanding of the temperature which electronics mounted in the ice would encounter, ice and water temperatures (just below the ice) were logged. Four temperature sensors were mounted on a 3-meter (10 ft) section of PVC. This pipe was then placed in a 4-inch hole drilled through the ice into water. The hole was then allowed to refreeze, and the sensors were logged every 10 minutes using the data logger described above. These sensors were placed at depths of 0.3, 0.91, 1.83, and 2.74 meters (1, 3, 6, and 9 ft). The bottom sensor was about 0.5 meter below the bottom surface of the ice.

Wind Speed and Direction

Sensors from a Taylor Windscope (Model D) were used to take wind speed and direction measurements. This sensor uses a vane mounted on a potentiometer to measure wind direction and a three-cup rotor mounted on a small ac generator to measure the wind speed. The sensors were mounted on a mast approximately 6 meters above the ice.

The wind speed indicator was calibrated (in a wind tunnel) using the DACU as the ac-voltage measuring device. Employing the same instrument for calibration, as well as for field measurement, avoids possible problems due to generator loading or the voltage measurement being frequency dependent. Calibration data showed a linear response and was fitted to a linear equation for field measurement reduction.

The direction sensor was oriented to point with respect to grid north. Grid north is determined by noting the direction of the sun's shadow at 1200 GMT. At this time, the shadow will point parallel to the prime meridian in the direction of grid north. Although grid north is determined very accurately using this method, pointing the sensor involves some error. In addition, a dead spot on the direction potentiometer results in about a 3-degree error. Possible floe rotation during the exercise could also add to the direction error. Highly accurate measurements of wind direction were not needed for this

experiment, and the above errors were not serious. Comparison with floe-drift directions indicate that large errors were not present.

Barometric Pressure

A YSI 2014 series barometric-pressure transducer, calibrated for use between 28 and 32 inches of mercury, was used to measure barometric pressure. A center-tap potentiometer is used as the output mechanism, and the instrument is calibrated using the ratio of the center-tap resistance to that of the total resistance.

During recording, the ratio described above was determined and stored for later recording and analysis. To convert to engineering units (inches Hg), a linear equation was fit to calibration data supplied by the factory. The barometer is accurate to about 0.02 inch Hg.

CTD Stations

An Ocean Sensors, Model OS100, CTD device was used for producing bathometric profiles. It is lightweight, battery powered, and records internally. A small battery-powered winch was used to lower the instrument.

The hydrohole was drilled through the ice in a corner of the generator tent. An 8-inch PVC tube was then inserted in the hole, and a heating cable was placed inside the tube to keep the hole from refreezing.

The normal method for doing a profile was to set up the CTD device to commence recording after a wait of 20 minutes, which provided adequate time for the device to reach temperature equilibrium with its surroundings. The device was then placed at the bottom of the hydrohole.

The device was lowered by allowing the winch to freewheel out. An extra 10-lb weight was added to it to ensure adequate torque on the drum. A drop rate of between 30 and 60 meters per minute was maintained by the operator using friction to control the rate. The device was raised by using battery power.

No method was available to monitor the device during the cast. When the cast was completed, the device was connected, via an RS-232 interface, to a portable computer; and the profile was downloaded and stored for analysis.

Normally, two to four samples per meter were recorded, with each sample consisting of a record of day, time, temperature, pressure, and conductivity. Profiles were produced to a depth of between 600 and 700 meters. In addition, for about 200 minutes, one time series was recorded at a fixed depth of 181 meters.

DATA

NAVIGATION

Camp Position

Because of the position of satellites on the horizon in the high Arctic, the satellite navigator did not provide as accurate a position as would normally be expected. The scatter in the data points indicated that the ARGOS system provided better position data in this instance. No work has been done to determine the absolute accuracies of these two systems for this trip or to calculate the amount of error in drift rates or directions.

Camp Crystal was set up on March 30 at $88^{\circ} 00.2' \text{ N } 110^{\circ} 32.6' \text{ E}$. This position was determined by project aircraft. The camp was abandoned on 31 May 1988 and was located at about $88^{\circ} 13.43' \text{ N } 70^{\circ} 03.9' \text{ E}$. Shown in figure 1 is a map of camp position. The map only includes dates when an ARGOS transmitter was located in the camp and covers the period from April 11 (Julian day 102) until April 29 (Julian day 120). For comparison, note that other data in this report are plotted starting at Julian day 108. (Figure 2 shows the direction of the floe drift.)

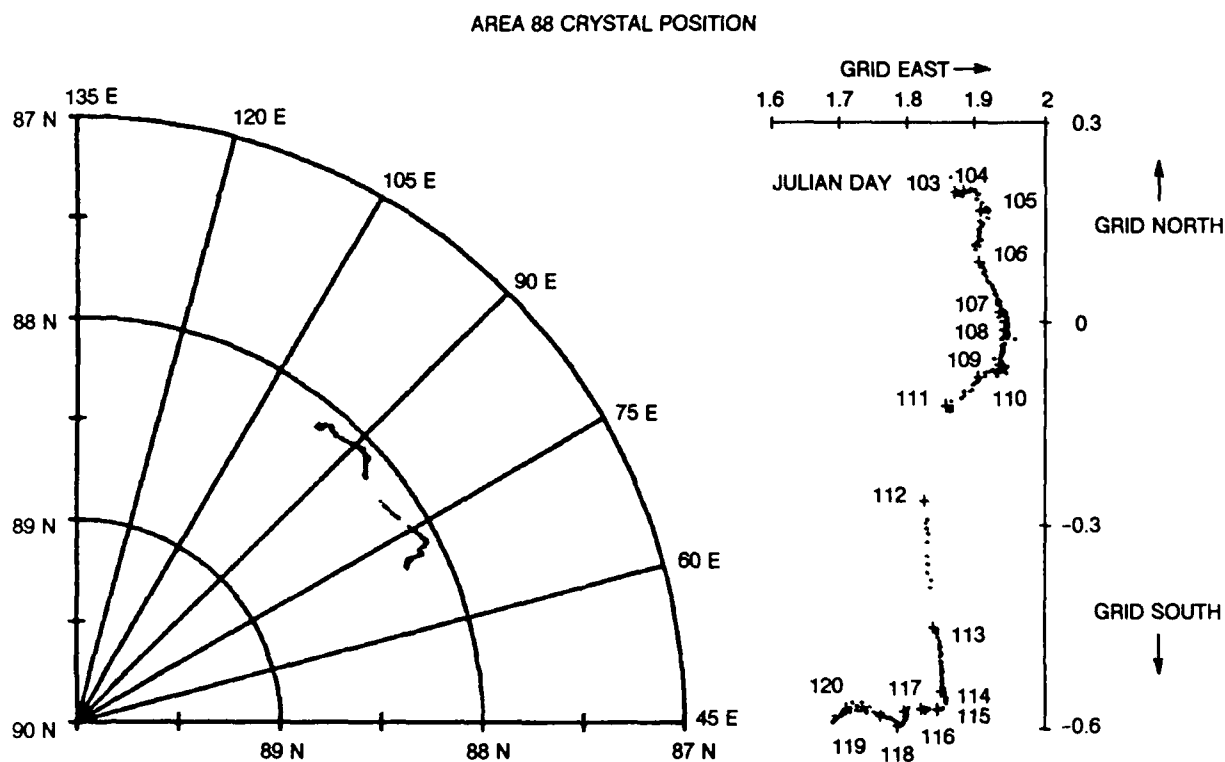


Figure 1. Map of Camp Crystal position.

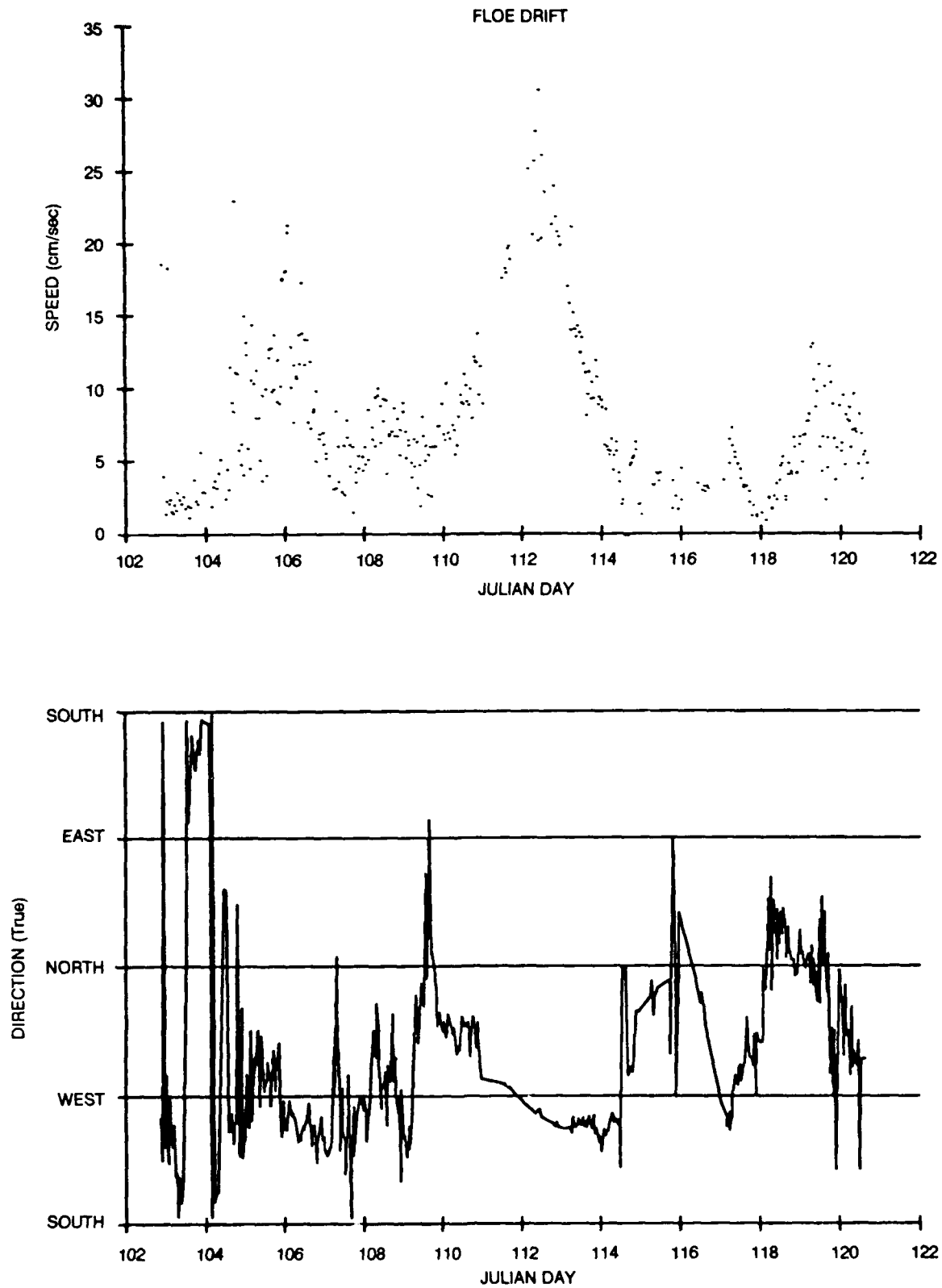


Figure 2. Drift direction.

Camp Drift Rate and Direction

Drift rate was calculated by dividing the great-circle distance between two positions by the elapsed time between the position readings. To smooth the data, a moving separation of six data points is used. The time for a drift rate point is the midpoint between the two times recorded for the position point.

Using the same method and the appropriate formula, true drift direction was calculated. To compare drift direction with wind direction (figure 11, shown later), which is measured relative to grid north, drift directions were also calculated using grid. For an explanation of grid coordinates, and great-circle calculations for distance and direction, see Bowditch (1984).

WIND SPEED AND DIRECTION

Wind, ocean current, and drift rate, which are shown to be related, are all dominated by a minor storm which occurred between days 110 and 114. This storm produced winds on the order of 30 mph. Figure 3 shows wind speed and direction.

TEMPERATURE

Temperatures are shown in figure 4. At about day 111, the hole completed refreezing sufficiently to cause the water temperature and the 1.83-meter ice temperatures to diverge.

The temperature of the thermometers was calculated to three decimal places, and examination of the data shows that the resolution of the thermistors was probably good to 0.002 degree or better. Although the thermistors were calibrated, they could not be calibrated accurately at the temperatures encountered in this experiment. Despite this, the thermistors in the ice and the thermistor in the water are probably accurate to better than 0.05-degree centigrade. Numerous extraneous effects cause the accuracy of the air thermistor to be less, probably about one degree centigrade. No in-depth error analysis has been done, however, the water thermistor agrees with the surface temperature of the CTD sensor within 0.02 degree, and the 1.83-meter sensor agrees with the water sensor (before the hole froze) within 0.005 degree. For this experiment, these accuracies are sufficient.

Some interesting data points that are not readily apparent on the graph are turning points of the three ice curves. For the 0.3-meter sensor, a negative gradient exists until day 110 at about 1200 GMT. The minimum temperature encountered was -17.94 degrees centigrade. The gradient was then positive, until the end of the experiment, when the temperature was -13.23 degrees centigrade.

The 0.91-meter thermistor had a negative gradient until day 112, at about 0200 GMT, when the temperature was at -12.3 degrees centigrade. Its gradient was then positive for the remainder of the experiment, ending up at -10.309 degrees centigrade.

The 1.83-meter thermistor had a negative gradient until day 117, at about 1800 GMT, when its temperature was -3.69 degrees. It maintained this temperature within about 0.005 degree, until the end of the experiment.

The water thermistor remained at -1.733 (± 0.004) degrees centigrade for the entire experiment.

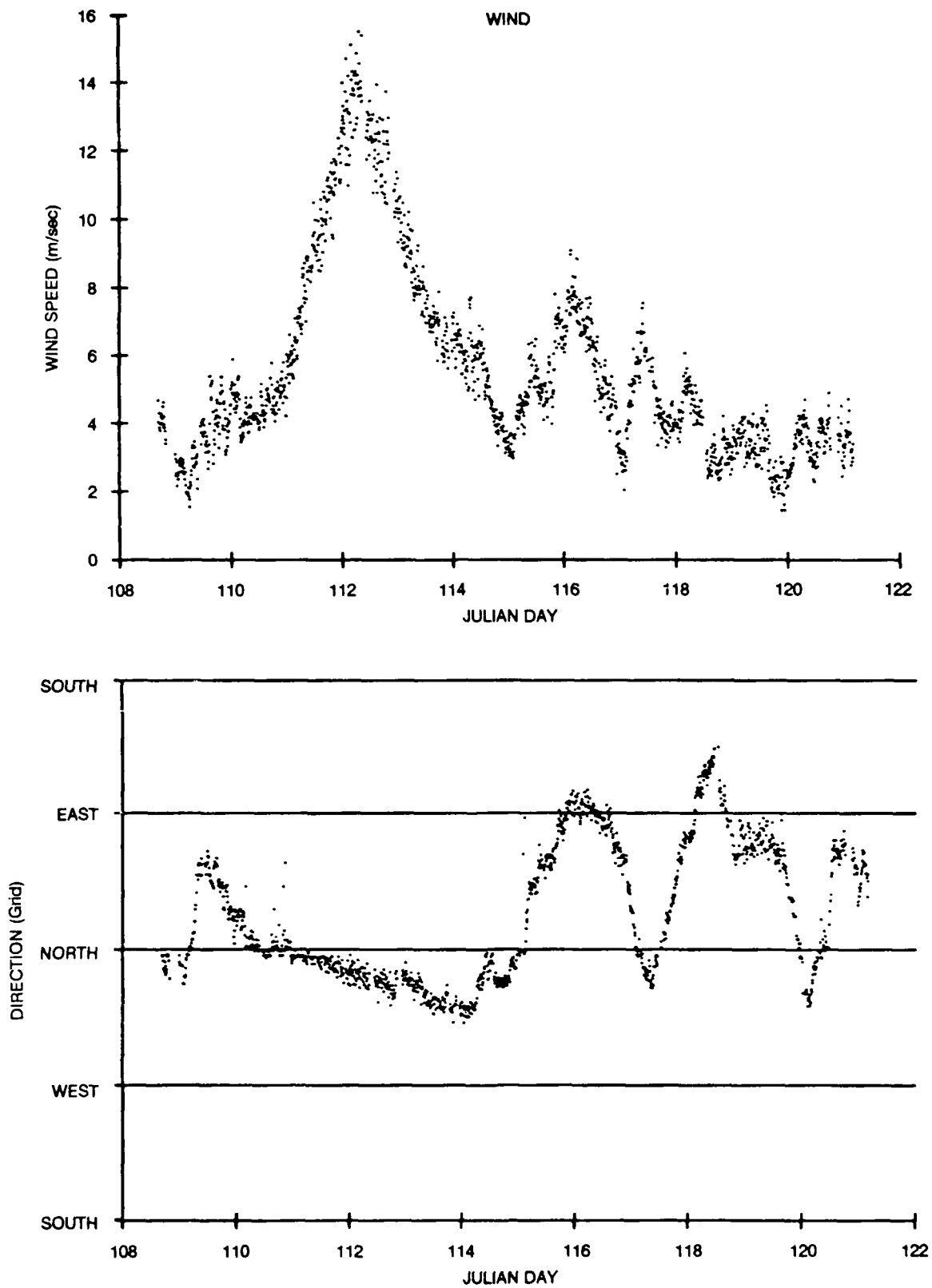


Figure 3. Wind speed and direction.

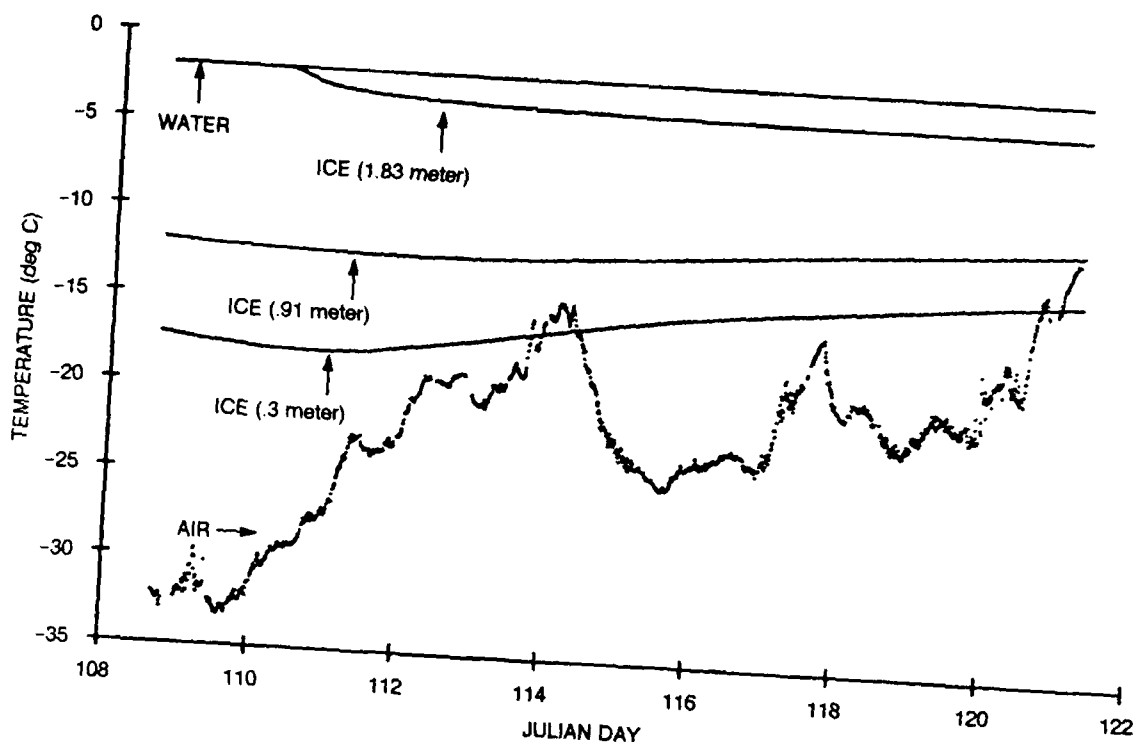


Figure 4. Temperature measurements.

BAROMETER

Figure 5 shows the barometric pressure for the data recording period. The results (or cause?) of the minor storm occurring between days 110 and 114 are clearly apparent.

OCEAN CURRENT

Current meter results are shown in figure 6. The meter was hung at a depth of 197 meters. No extra weight was placed on the meter, so during high relative current, the depth would decrease as the current meter responded to the drag. This response resulted in a minimum depth of about 90 meters.

Current meter direction is measured using a fluxgate compass mounted in the wet end of the current meter. The data have been offset to run from -90 to 270 degrees, instead of from 0 to 360 degrees, for a nicer plot appearance. The magnetic direction measured by the current meter and the grid or true directions has not been correlated. If one looks at wind direction (figure 3) or drift direction (figure 2), obvious similarities can be seen. Drift, current, and wind relationships will be discussed more fully in a later section.

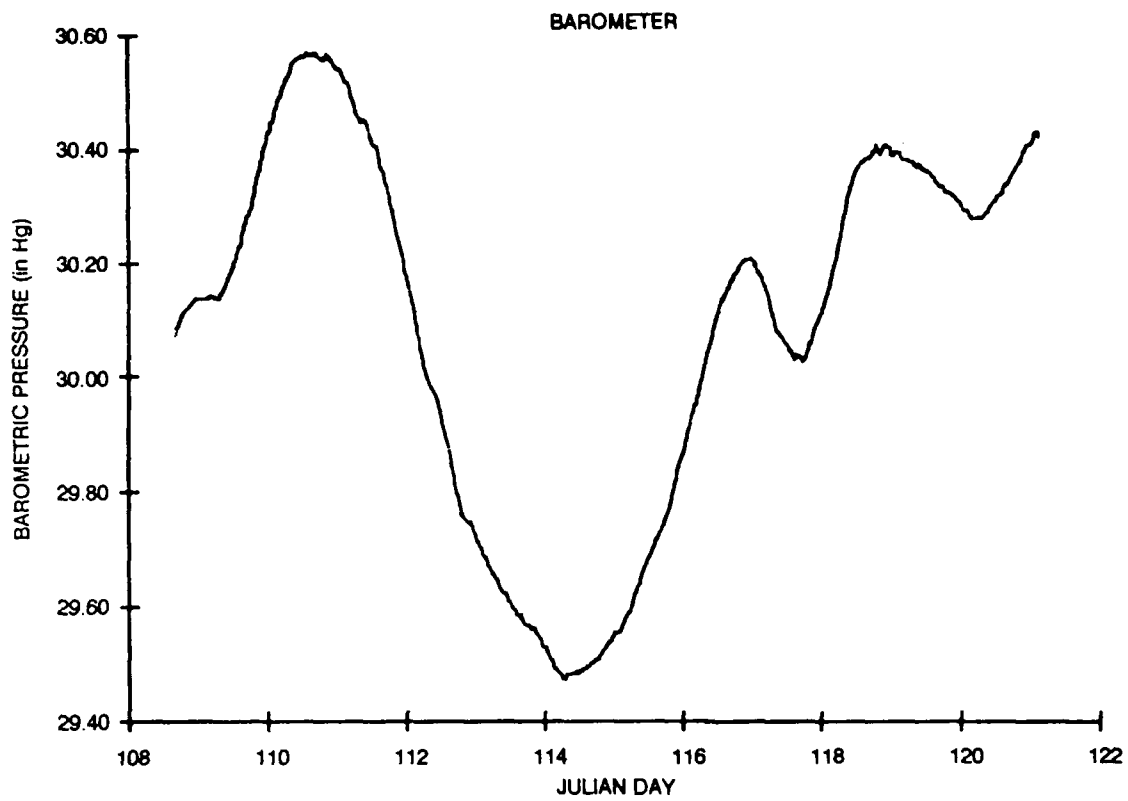


Figure 5. Barometric pressure.

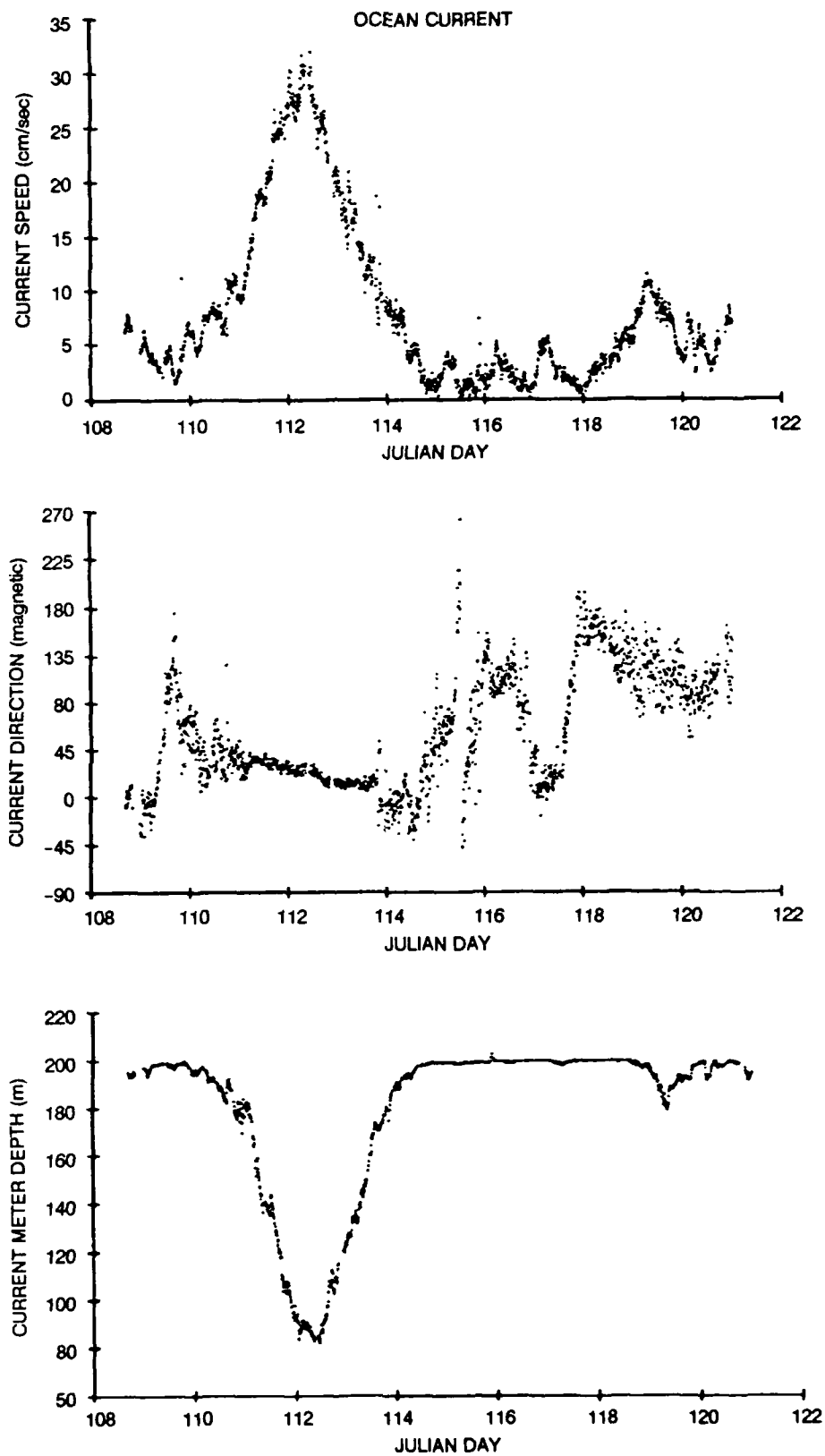


Figure 6. Current meter results.

CTD OPERATIONS

Fourteen CTD stations were established. Station 6 was not used because of a problem with the calibration constants entered into the probe, which caused erroneous conductivity cell readings. Station 13 was a high-resolution, low-accuracy cast over a limited range and is also not included.

Station 10 was a time series at a constant depth and is discussed below. Its purpose was to gather data on internal wave activity. (It is not shown in Appendix A.)

Table 1 gives dates, times, and positions for the CTD data. Graphs of sound speed, temperature, salinity, and density (σ_t) are available in Appendix A for 11 of the 14 CTD stations.

Formulas for processing salinity and density were obtained from the 1983 version of the UNESCO report, "Algorithms for Computation of Fundamental Properties of Seawater." Sound speed was obtained using a formula provided by Lovett.* This equation is a later version of those provided in Lovett (1978).

Table 1. CTD stations: date, time, and position data.

Number	Date	Time	Longitude	Latitude
01	04/15/88	1440	89° 33.1' E	88° 02.9' N
02	04/18/88	1451	87° 46.6' E	88° 04.3' N
03	04/21/88	1828	77° 55.5' E	88° 07.7' N
04	04/22/88	1557	74° 19.4' E	88° 04.7' N
05	04/23/88	1211	73° 04.0' E	88° 03.7' N
06		Not Included		
07	04/24/88	1710	72° 28.6' E	88° 04.7' N
08	04/25/88	1414	72° 06.1' E	88° 06.4' N
09	04/26/88	1209	72° 06.1' E	88° 06.3' N
10	04/26/88	1340	71° 26.1' E	88° 06.5' N
11	04/27/88	1219	71° 17.1' E	88° 07.1' N
12	04/28/88	1138	71° 21.6' E	88° 09.9' N
13		Not Included		
14	04/29/88	1118	70° 31.3' E	88° 12.2' N

PROFILES

Abundant fine structure (figure 7) exists in the central Arctic. In particular, note the small 1- or 2-meter steps at depths between about 100 meters to about 250 meters. They are probably caused by double diffusion. The large steps on the order of 10 to 50 meters occurring below the temperature maximum are not well understood. Both types of layering are covered in more detail in Nesyba (1971).

As shown in figure 8, salinity spiking is evident in these profiles. This is due to the sharp temperature gradients in the layers and the relatively slow (about 300 ms) time constant of the temperature sensor in relation to the conductivity cell (about 20 ms). The line drawn through the same data point of temperature, conductivity, and the resulting salinity, clearly shows the temperature lag and the resulting salinity spike.

* Personal communication.

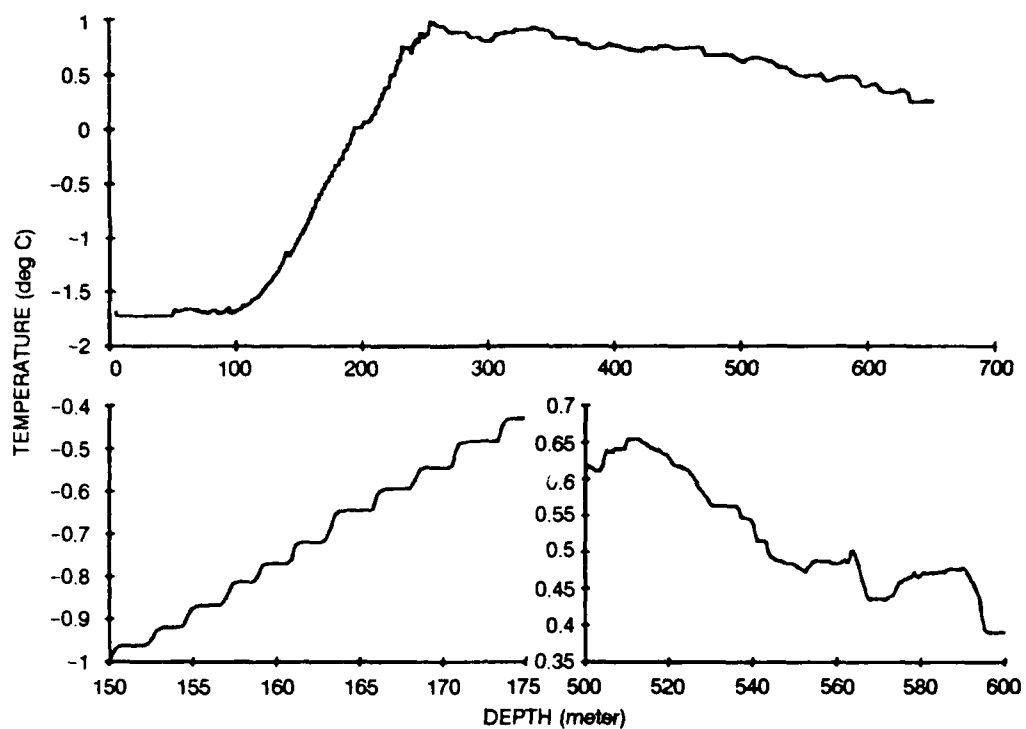


Figure 7. A typical temperature profile showing step-like structure.

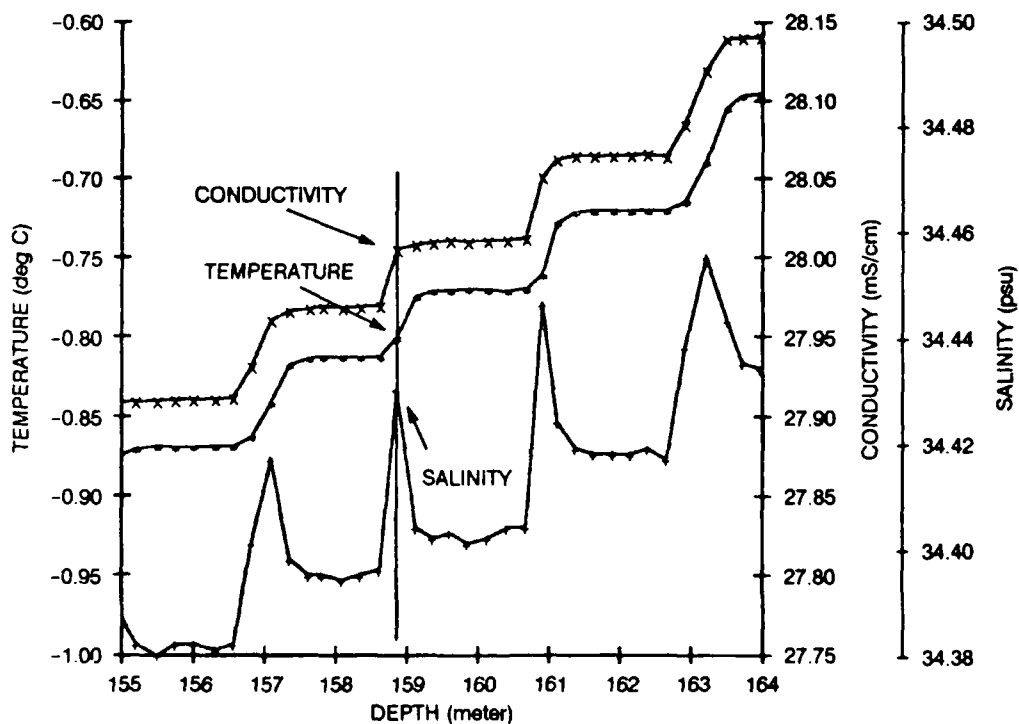


Figure 8. An example of salinity spiking.

TEMPERATURE TIME SERIES

Figure 9 shows the temperature for station 10 as a function of time, and the temperature for station 9 as a function of depth. The mean depth for the time series (station 10) was 181.3 meters, with a standard deviation of 0.11 meters. The maximum value during the recording period was 181.6 meters, and the minimum value was 180.9 meters.

An examination of figure 9 shows that the peak-to-peak amplitude of water column movement is about 8 meters. This is the distance between steps on the station 9 profile, which is indicated in the station 10 time series by the clipping effect.

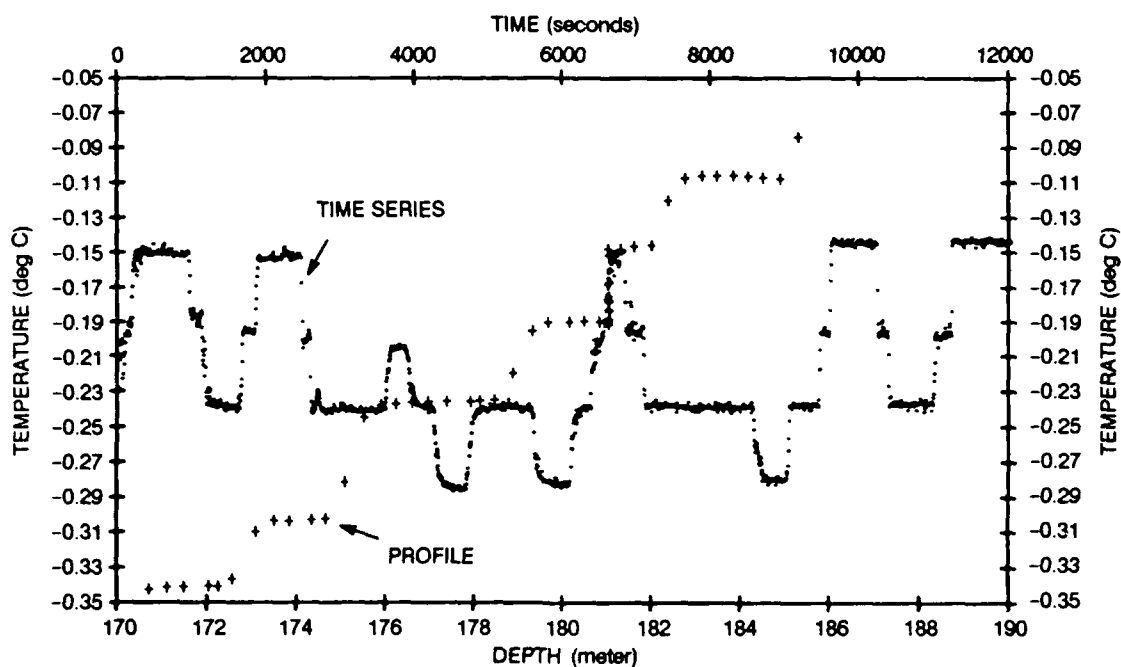


Figure 9. Station 10 temperature (function of time); station 9 temperature (function of depth).

COMPARISONS OF DRIFT, CURRENT, AND WIND

Figures 10 and 11 are provided to give some insight into the actual current speed and the effects of wind on camp drift.

Figure 10 shows a plot of drift rate and current speed superimposed at the same scale. Errors in drift rate are probably large, so true current has not been calculated.

Figure 11 shows an overlay of drift direction and wind direction. Both are calculated using the grid coordinate system. The camp drift axis (left axis) shows a primary direction of south, whereas the wind axis (right axis) shows a primary direction of north. This difference is because the wind direction is oriented with respect to where the wind blows from, and the drift is oriented with respect to where the floe is drifting to. Another way of saying this is if the wind blows from the north, it will generate a southward force on the floe.

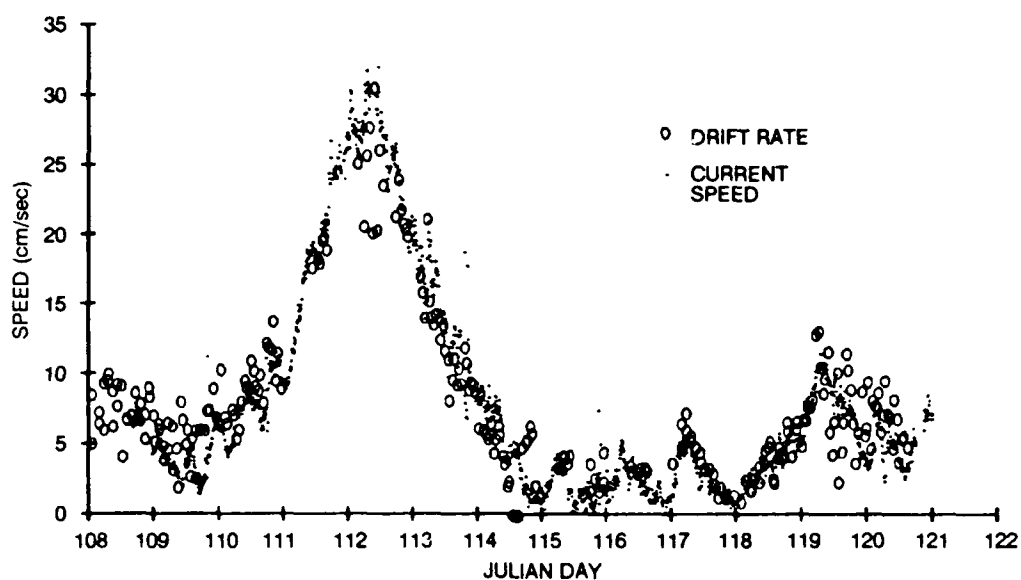


Figure 10. Drift rate/current speed.

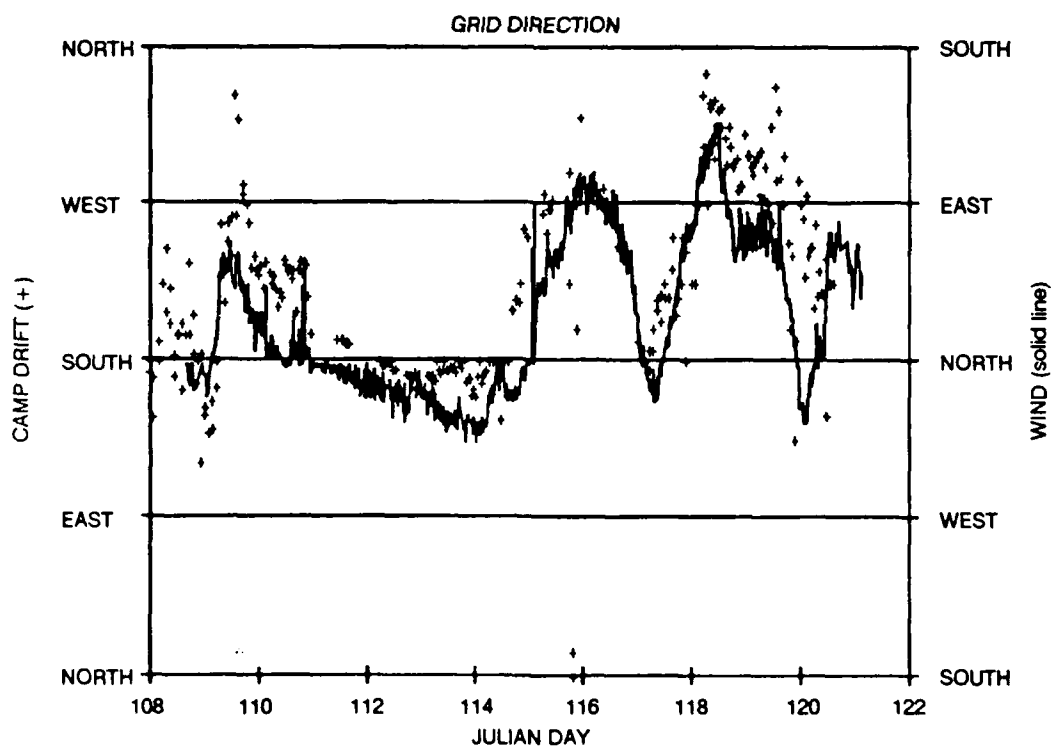


Figure 11. Drift direction/wind direction.

CONCLUSIONS

NAVIGATION

Probably the best method for logging navigational data is to place an ARGOS transmitter at the site for the duration of the project. It would be relatively inexpensive to buy such a transmitter, outfitted with some appropriate weather sensors, and to install it early in the camp operation. The data provided would then be a primary data set for position and weather data. In addition, the buoy would provide an additional source of data to base camps, should a radio blackout occur.

CTD DATA

In the macroscopic sense, CTD profiles show little variation. Station 14 is apparently the best profile in terms of density of data points and can probably be used for analyzing any acoustic data taken during this project.

In addition, figure 10 clearly shows the presence of internal waves.

Although quality CTD data were collected on this project, little analysis has been done. In particular, the mechanism of the large steps below the temperature maximum does not appear to be well understood. No data are available concerning the spatial extent nor stability of the steps.

The regularity of the steps should also be analyzed to determine if they could cause any odd acoustic affects.

TEMPERATURE

Figure 4 clearly shows a stabler and warmer environment in the ice than in the air. Unfortunately, the ice used for this experiment was first-year ice, less than 2 meters thick. This is not an adequate thickness for realistically testing ice temperature. In addition, air temperatures were not sufficiently cold for an adequate time to get a good indication of actual temperatures in the ice during a cold spell.

Although little question exists about the ability of ice to keep instrumentation relatively warm with respect to the air, it might be beneficial to install a multiyear system to log long-term ice temperatures. This system would provide data in a more realistic manner, both during the dark winter and the summer months. Ideally, the system would be placed in multiyear ice at least 3 meters thick to provide a more authentic profile. This type of system would be inexpensive and would not require a high data rate.

WIND, CURRENT, AND FLOE DRIFT

Figure 10 shows low current speeds during the period of this project, which seems to be normal in the central Arctic. Current measurements made in previous years in the central Arctic have always indicated speeds of less than 0.5 knot. Previous measurements were not compared to camp drift data, because of insufficient navigation data. Because current was only recorded at one depth, and because most of the data were gathered in the central Arctic during March and April, a firm conclusion cannot be made on actual current, speed, and direction in this area based on data I gathered. However, as a first approximation, one could estimate the current experienced by a wet-end system by the floe-drift rate. However, I want to emphasize that this estimate is only for systems in the central Arctic.

Figure 11 was included to show the effect of the wind on camp drift. For this project, the wind was undoubtedly the prime driving force on the floe. However, ice conditions for this year were very light. Heavier ice conditions might cause other forcing effects, and the effect of the wind might not be as clearly visible.

REFERENCES

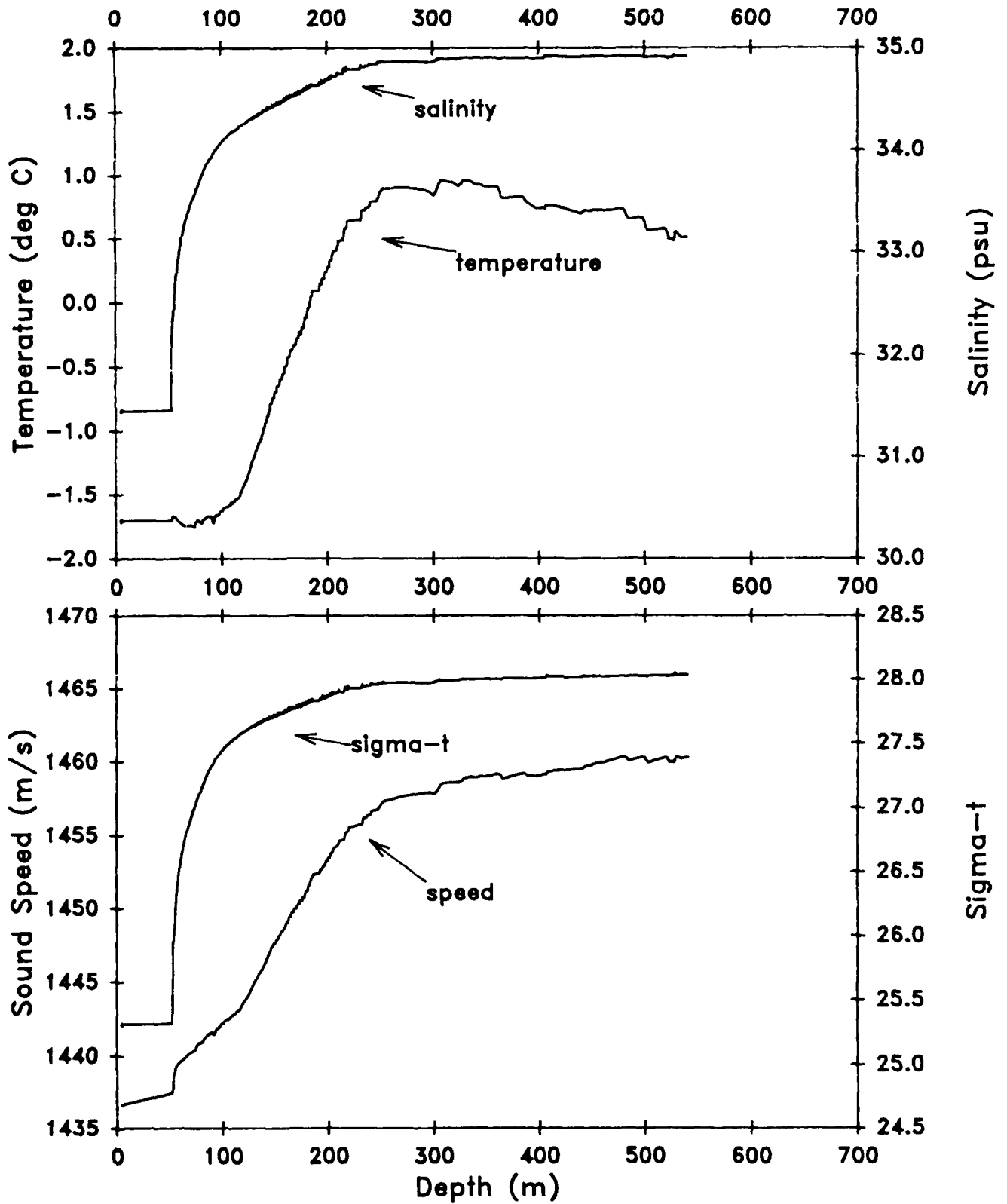
- Bowditch, N. 1984. *American Practical Navigator*. Defense Mapping Agency Hydrographic/Topographic Center.
- Lovett, J. R. 1978. "Merged Seawater Sound-Speed Equations," *Journal Acoust. Soc. Am.*, vol. 63, no. 6, pp. 1713-1718.
- Neshyba, S., V. T. Neal, and W. Denner. 1971. "Temperature and Conductivity Measurements under Ice Island T-3," *Journal of Geophysical Research*, vol. 76, no. 33, pp. 8107-8119.

APPENDIX A

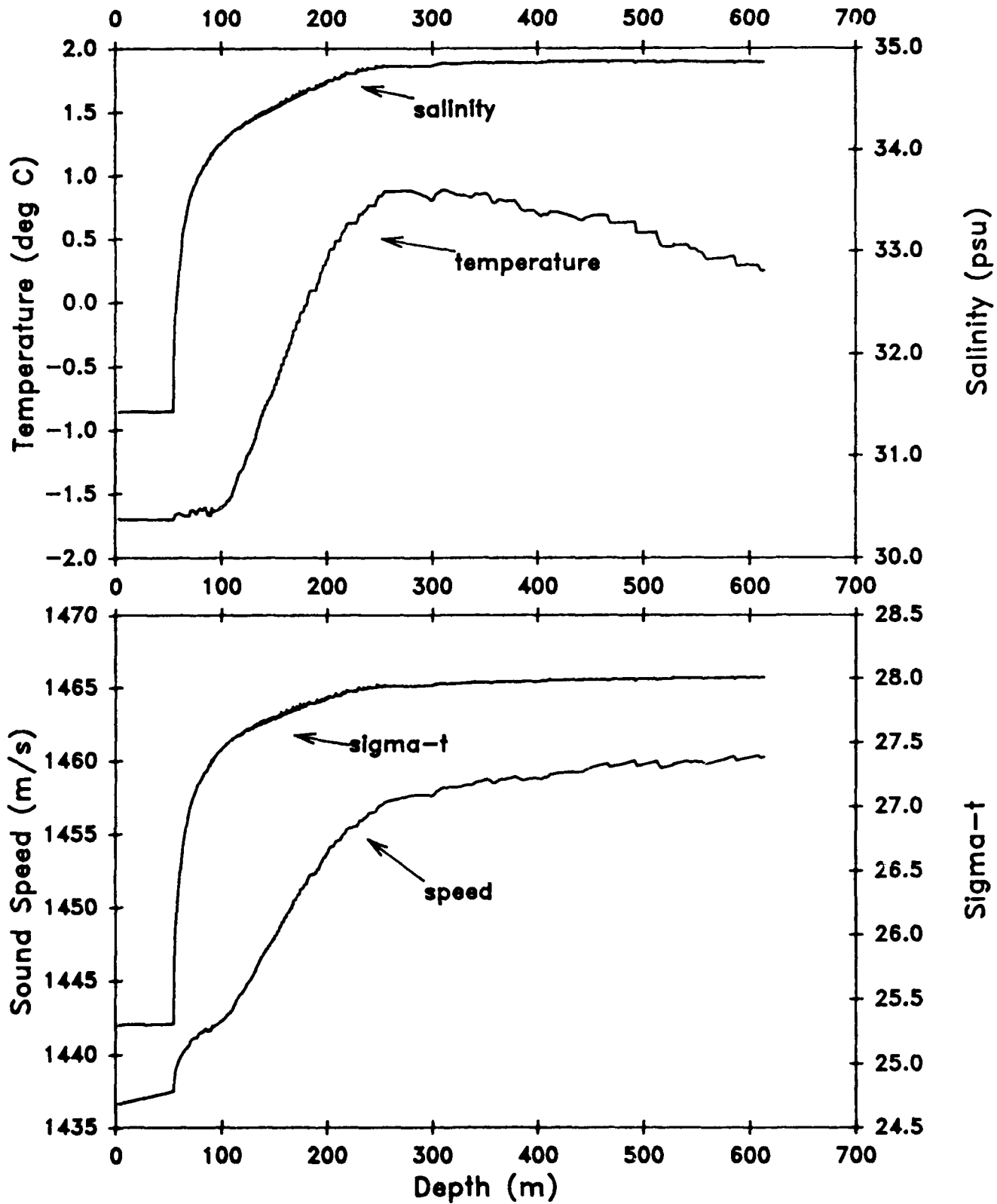
CTD STATION GRAPHS

This appendix contains graphs for CTD stations 1 through 5, 7 through 9, and 11, 12, and 14.

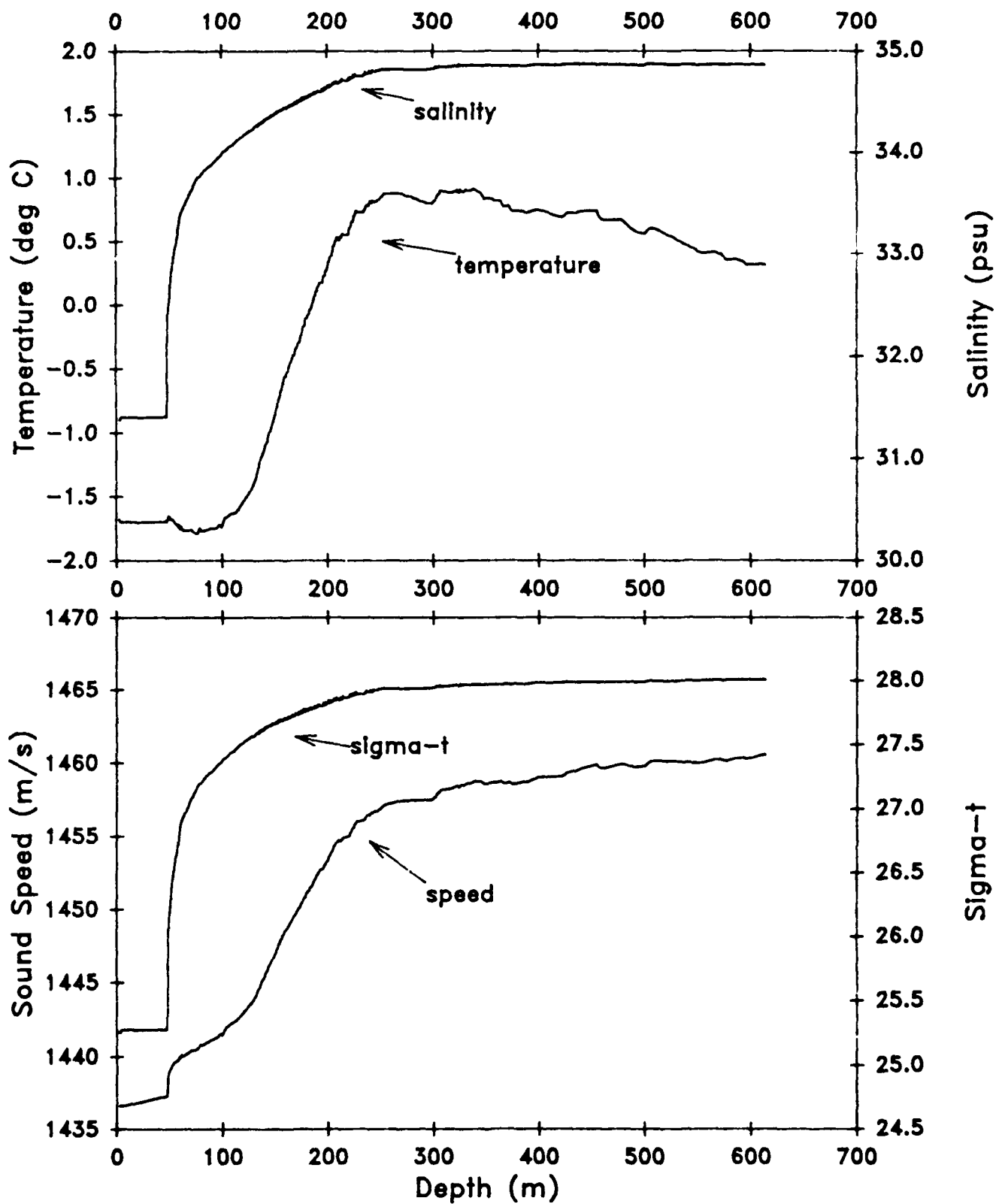
STATION 01



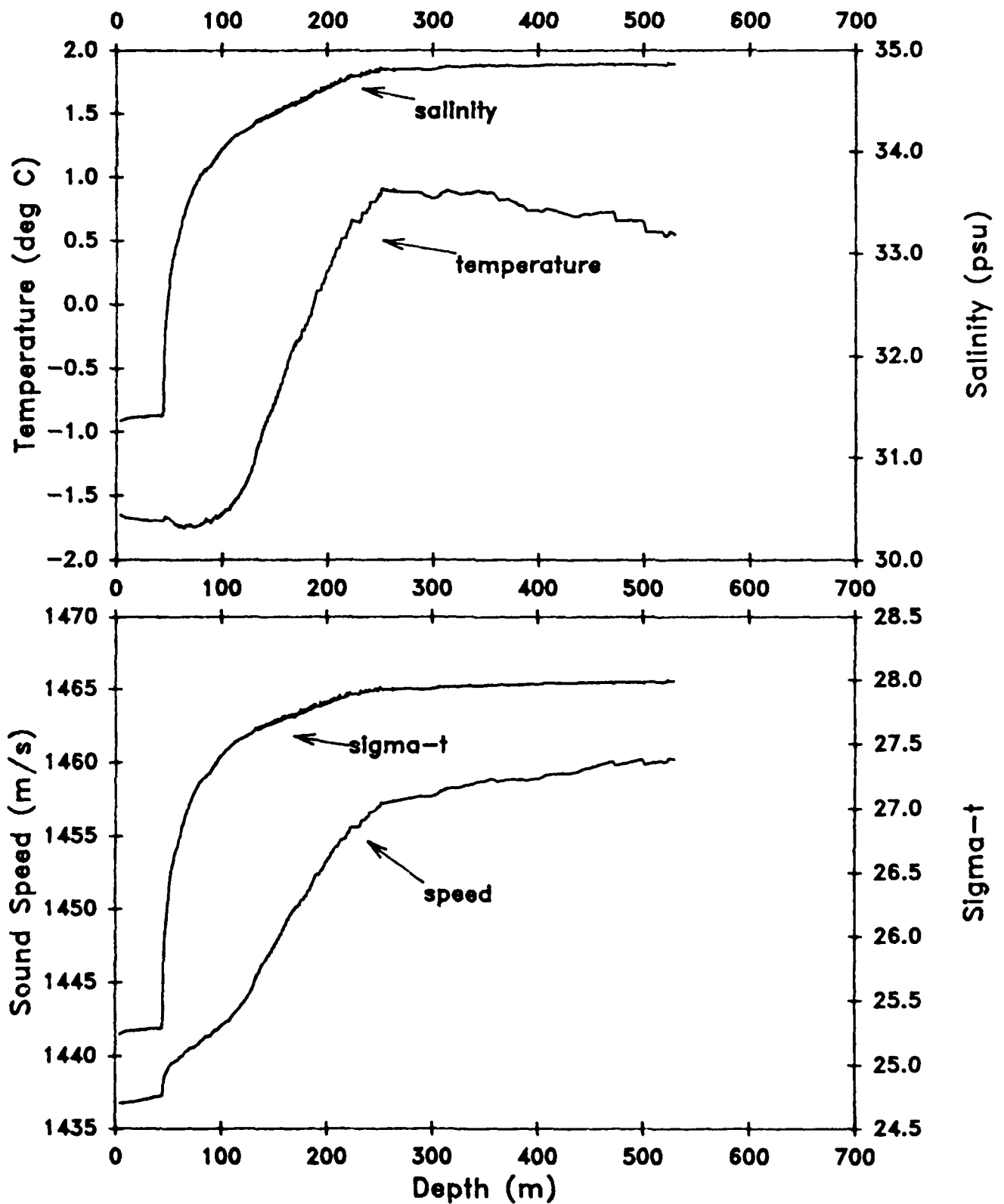
STATION 02



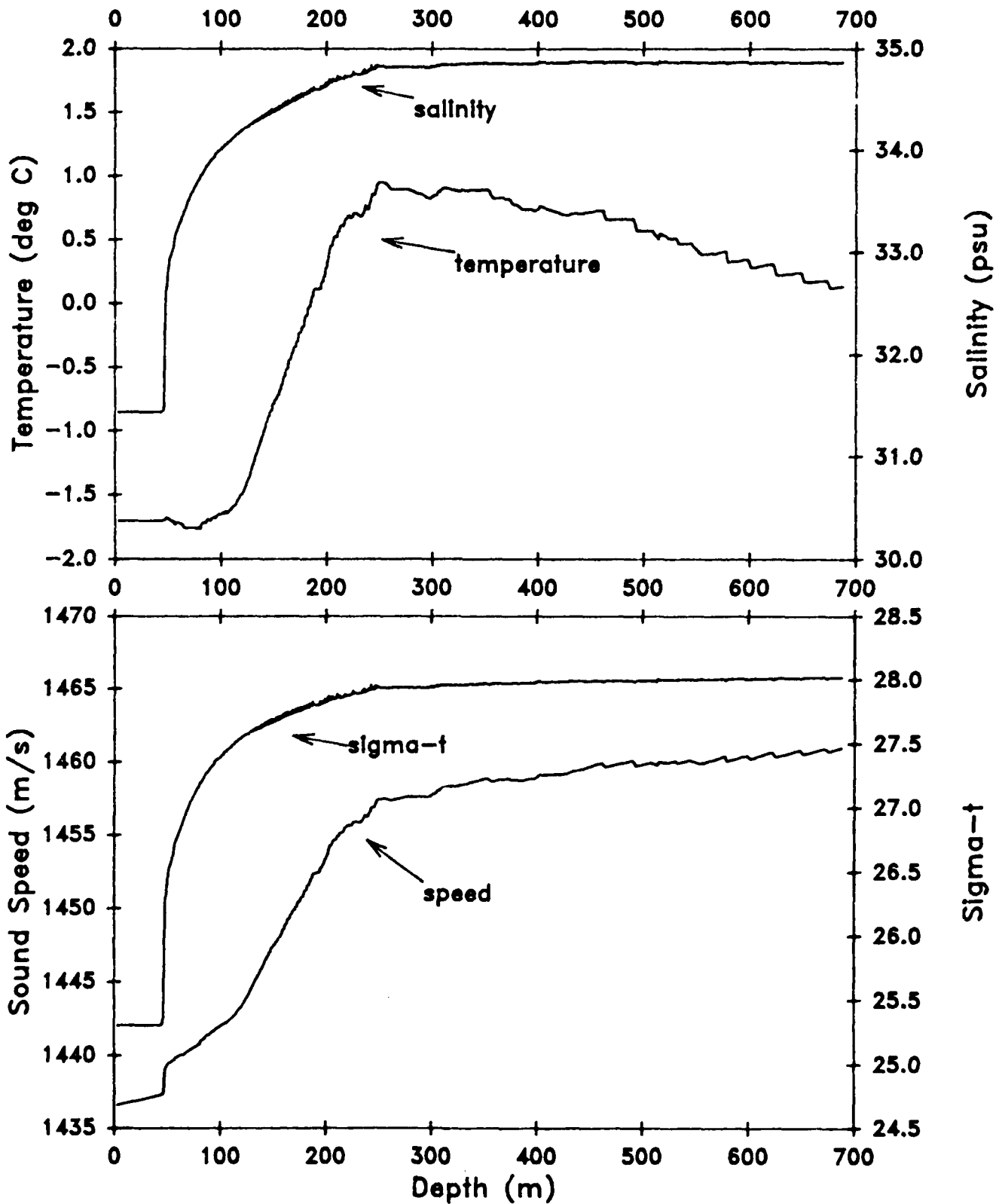
STATION 03



STATION 04



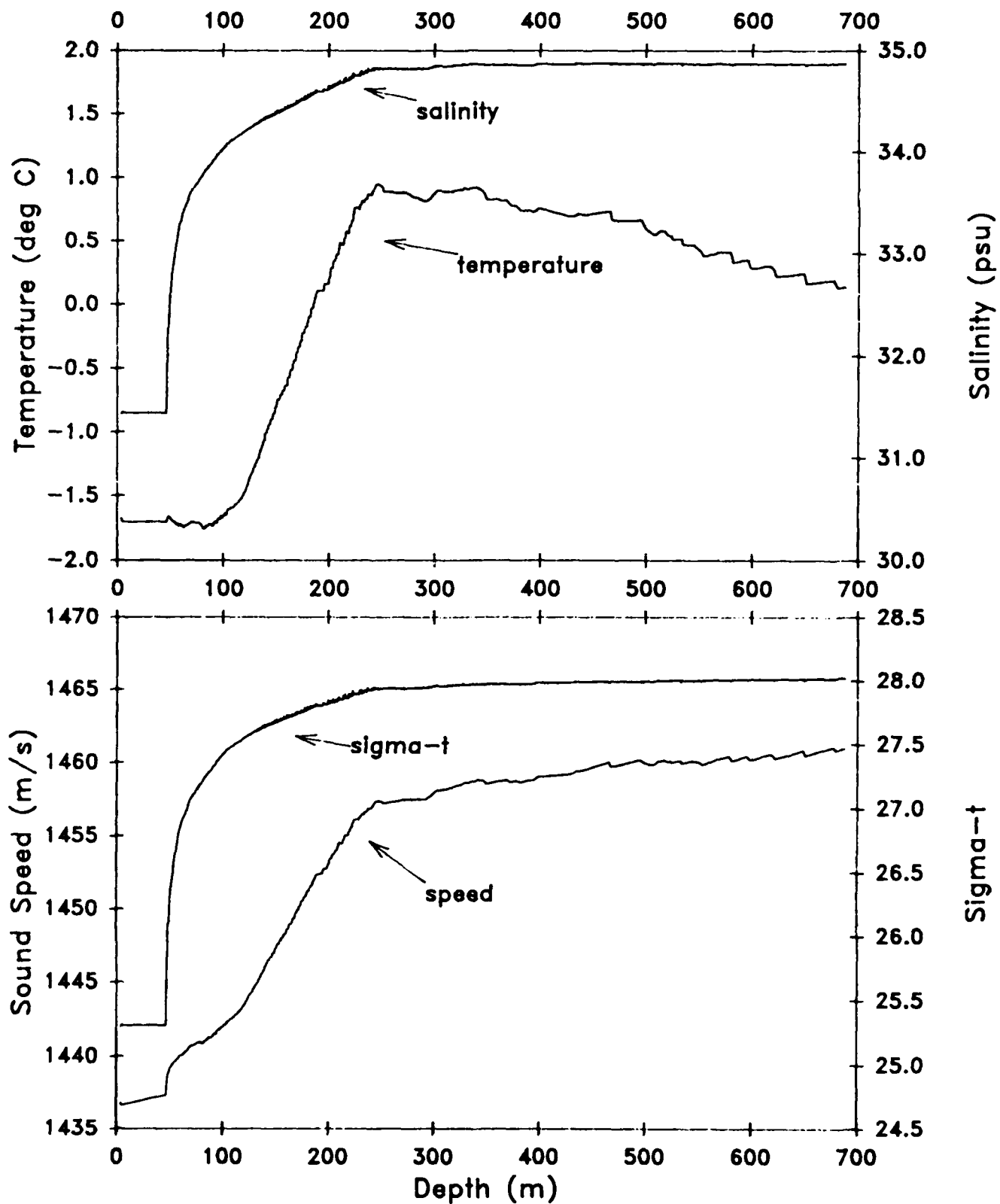
STATION 05



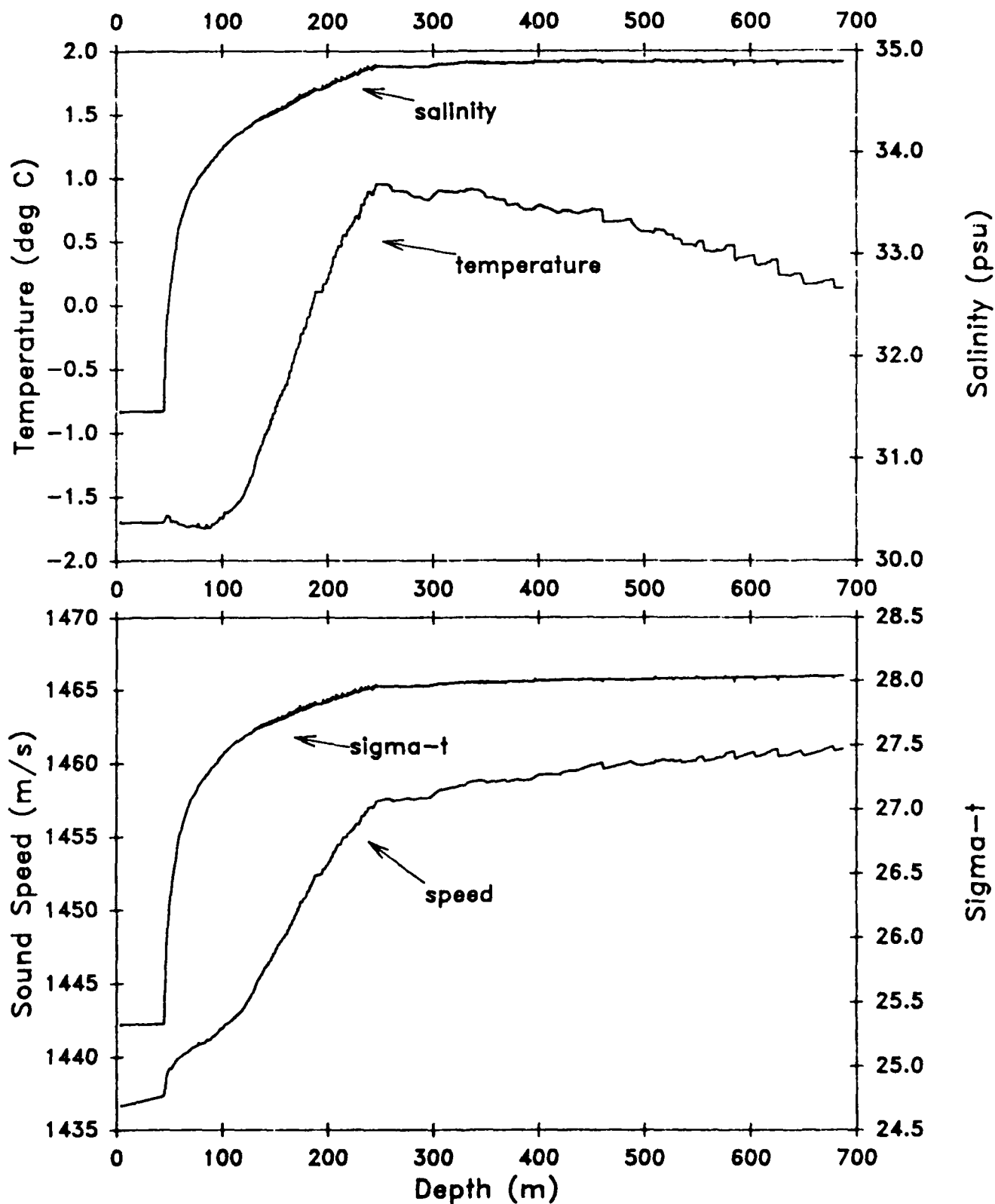
STATION 6

(Station 6 has been intentionally omitted.)

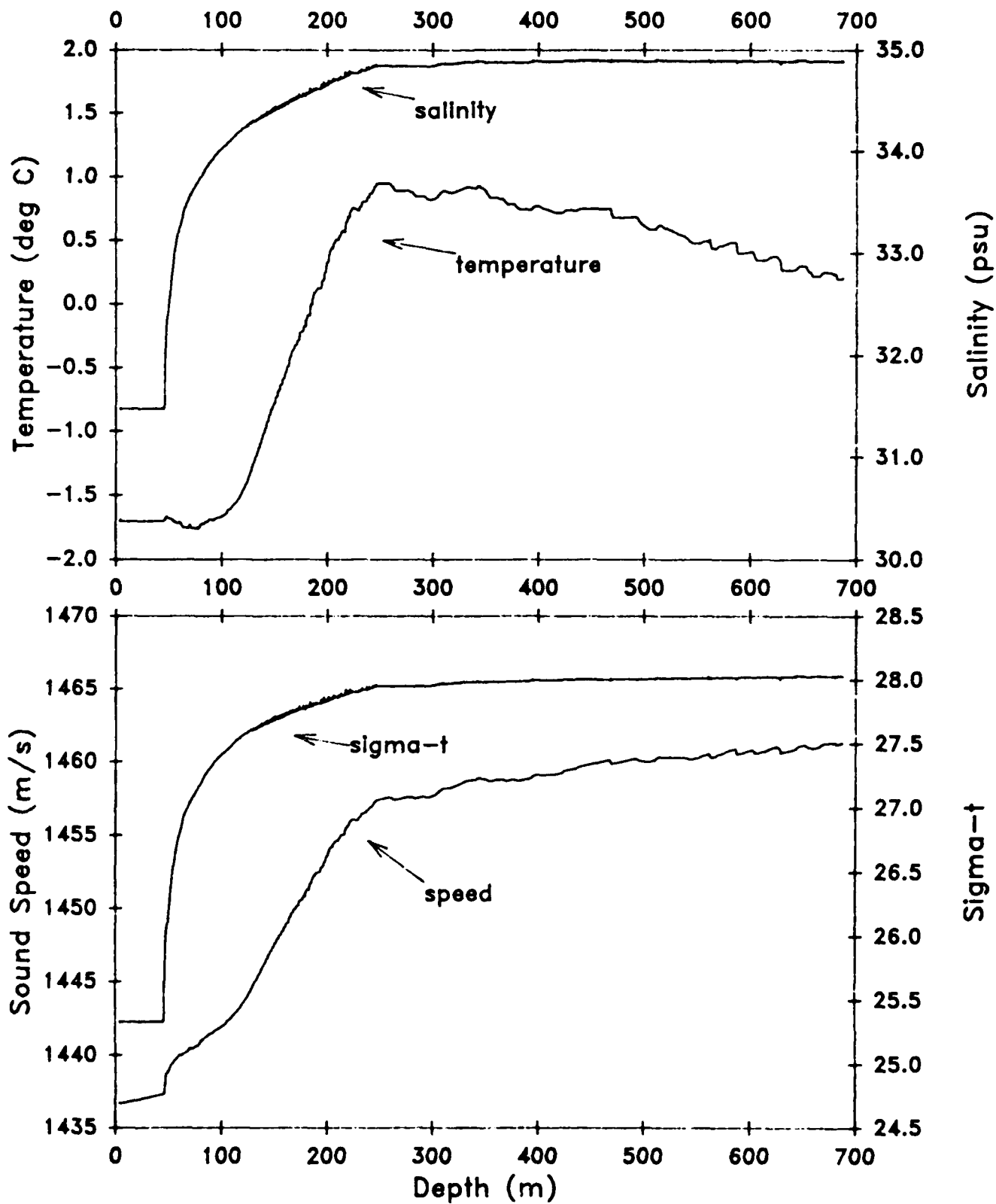
STATION 07



STATION 08



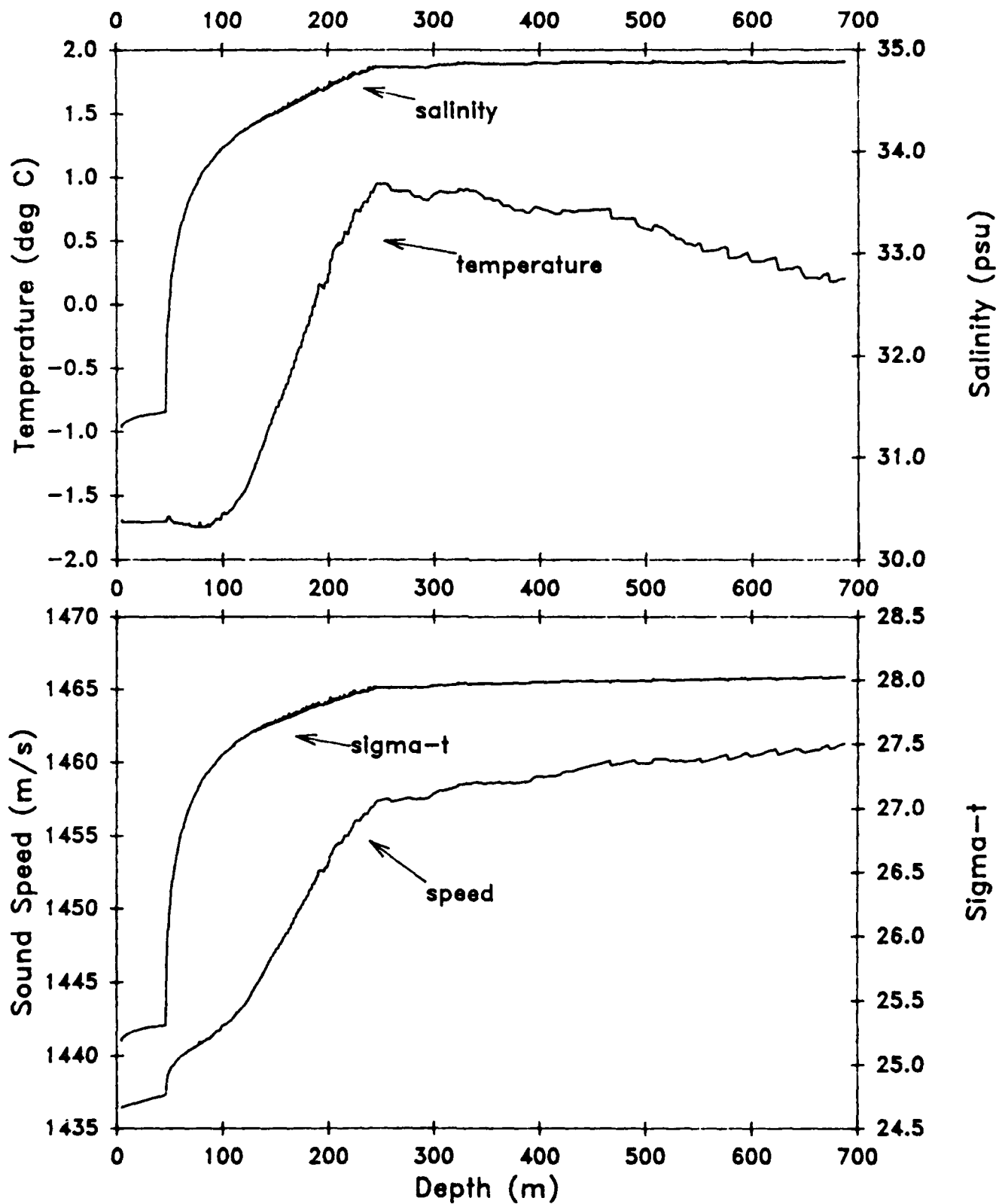
STATION 09



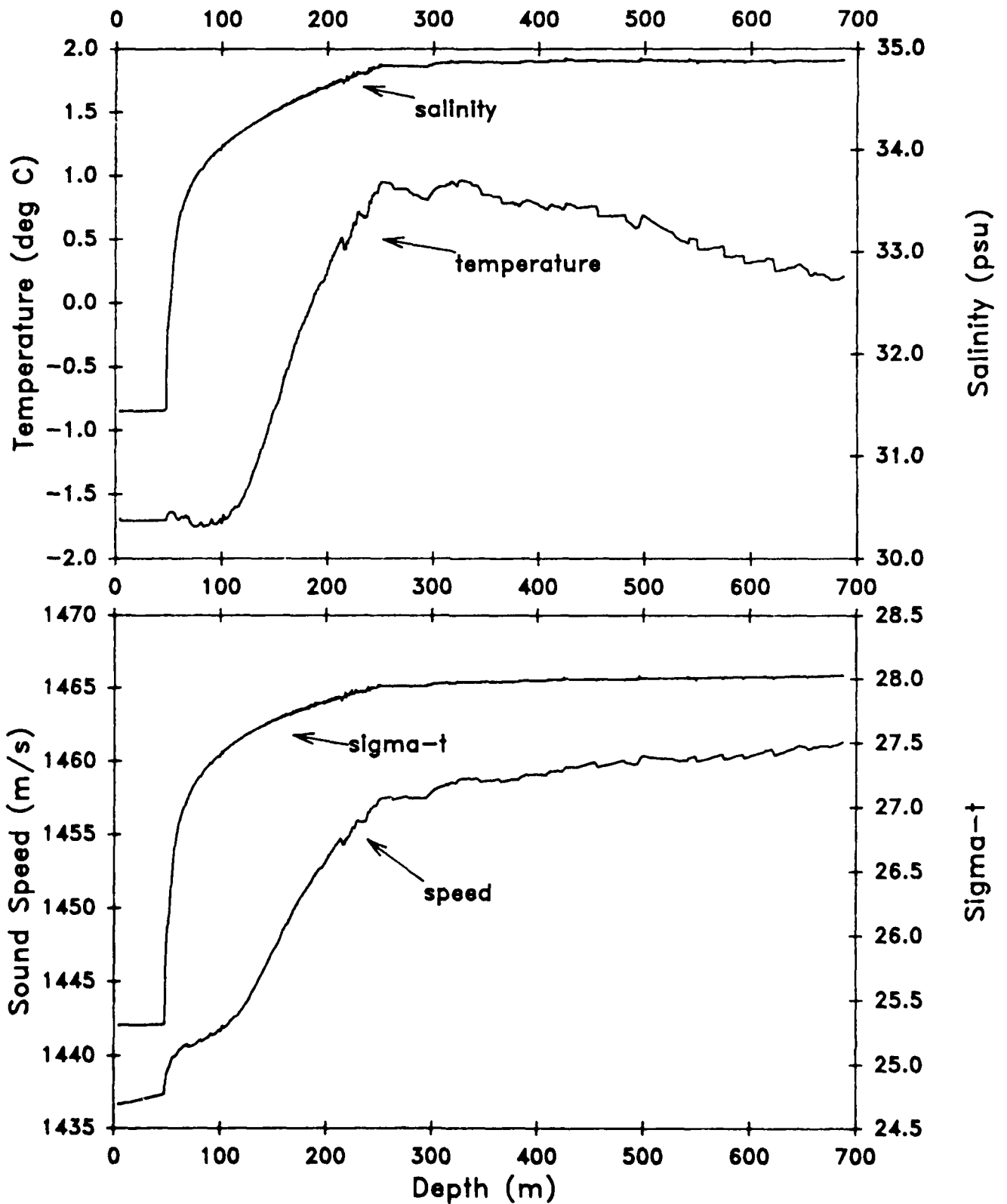
STATION 10

(Station 10 has been intentionally omitted.)

STATION 11



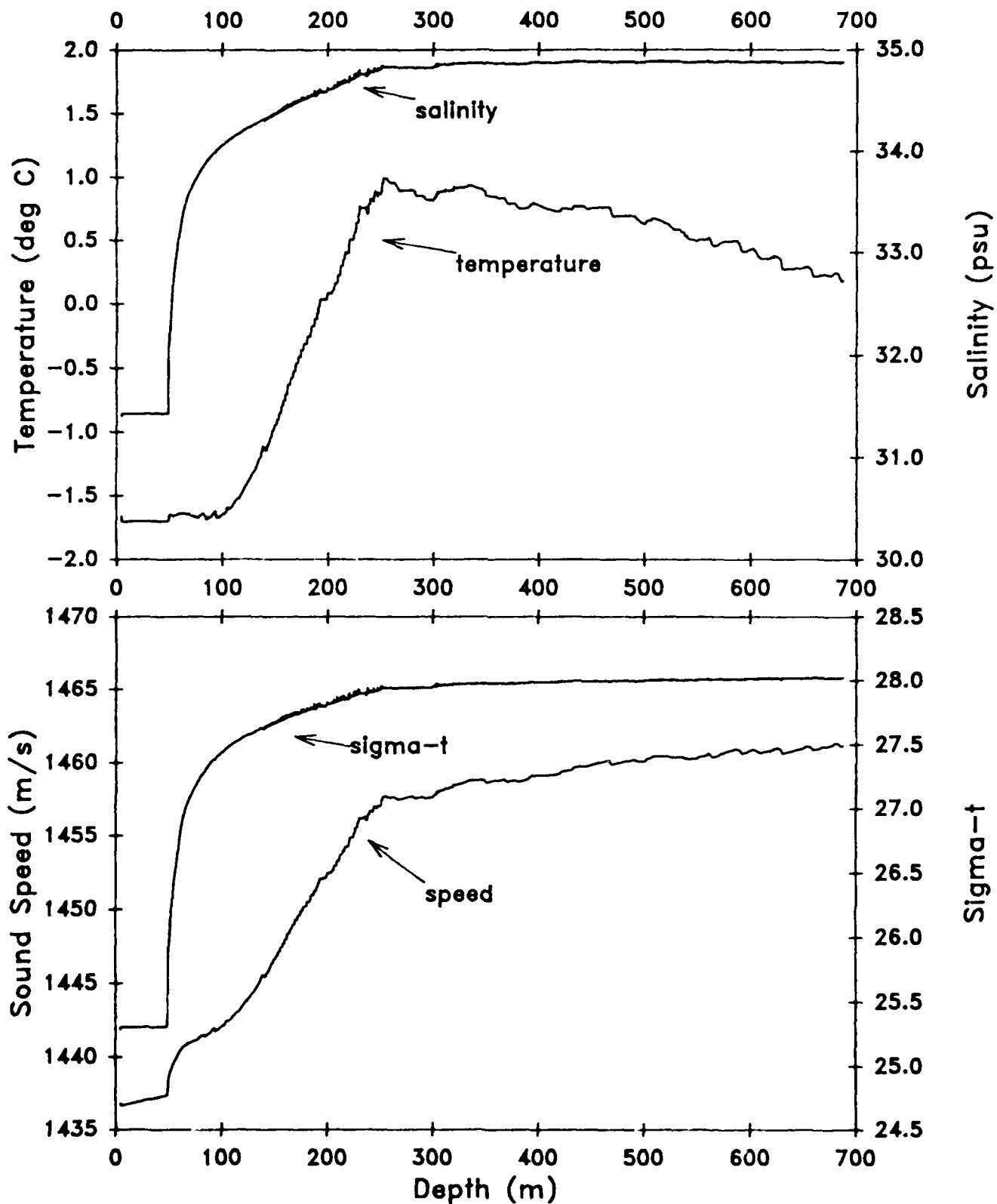
STATION 12



STATION 13

(Station 13 has been intentionally omitted.)

STATION 14



REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1 AGENCY USE ONLY (Leave blank)	2 REPORT DATE April 1990	3 REPORT TYPE AND DATES COVERED Final: March 1988 - April 1988	
4 TITLE AND SUBTITLE OCEANOGRAPHIC AND WEATHER DATA FOR ICE CAMP CRYSTAL DURING THE AREA 88 EXPERIMENT		5 FUNDING NUMBERS Project No.: RJ14I77/N03A Program Element: 62314N	
6 AUTHOR(S) R. R. Judd			
7 PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Ocean Systems Center San Diego, CA 92152-5000		8 PERFORMING ORGANIZATION REPORT NUMBER NOSC TR 1343	
9 SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Technology Arlington, VA		10 SPONSORING/MONITORING AGENCY REPORT NUMBER	
11 SUPPLEMENTARY NOTES			
12a DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b DISTRIBUTION CODE	
13 ABSTRACT (Maximum 200 words) During March and April of 1988, the U.S. Navy conducted an AREA (Arctic Research and Environmental Activities) experiment in the central Arctic to take and record environmental measurements of that arctic region. These measurements consisted of CTD (Conductivity, Temperature, and Depth) stations, ocean current, wind speed, air temperature, ice temperature, barometric pressure, and camp positions. CTD data were collected to about 700 meters, providing information to calculate sound-speed profiles. In addition, a time series, showing internal-wave activity, was collected at 181 meters. Wind speed ranged between calm and 15 meters per second. Ocean current and drift varied between less than 1 centimeter per second to 30 centimeters per second. To show their interrelationship, wind speed, ocean current, and drift are analyzed.			
14 SUBJECT TERMS AREA (Arctic Research and Environmental Activities) CTD (Conductivity, Temperature, and Depth) data environmental data collection		15 NUMBER OF PAGES 41	16 PRICE CODE
17 SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18 SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19 SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20 LIMITATION OF ABSTRACT SAME AS REPORT